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Are Certain Countries More Nimble in Completing Major Infrastructure Projects? A Cross Country Analysis of Infrastructure Capital Efficacy

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Abstract

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Keywords

Infrastructure, Construction, Efficiency, Bridge, Transportation

Disciplines

Civil and Environmental Engineering | Construction Engineering and Management | International Economics | Public Economics | Transportation Engineering

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Abstract

Discovering the drivers that lead to faster and more efficient completion of major infrastructure projects is important because there is a wide range when it comes to countries' ability to complete projects in a time and cost effective manner. This study looks at a dataset of the longest bridges in the world, which includes highways, high speed rail, expressways, and roads among other transportation infrastructure projects from 41 countries. This paper aims to discover whether some countries or regions appear to complete infrastructure projects faster than others and find which variables lead to faster completion of bridges as measured by feet built per day through various best fit models. It is concluded that a more recent start date, greater bridge length, and stronger property rights are positively correlated with completion speed of a bridge and Gross Domestic Product per capita is negatively correlated. This study also concludes that further research is needed to validate and replicate the results with a larger data set that has more bridges per country examined.

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Economics, Statistics, International Affairs, Public Policy

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1.1. Introduction

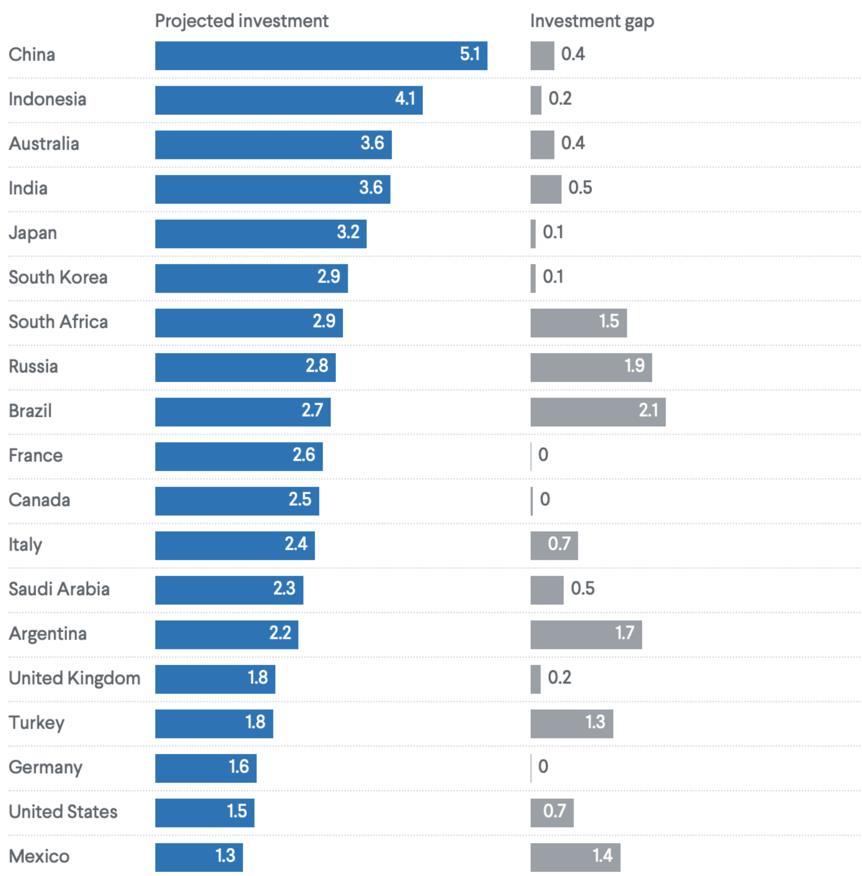
Understanding the drivers that lead to the efficient completion of major infrastructure projects is topical, given the wide range in countries' abilities to complete construction projects in a timely and cost effective manner. This study looks at a dataset of the longest bridges in the world, which includes highways, high speed rail, expressways, and roads among other transportation infrastructure projects from 41 countries and aims to find whether some countries or regions appear to complete infrastructure projects faster than others, as well as explore which variables are correlated with feet built per day, which is an efficiency metric.

The motivation behind choosing bridges to evaluate this phenomenon was because they are relatively similar in structure across geographies, yet the speed of completion as well as the cost varies greatly; furthermore, bridges have a far reaching economic impact. The reason construction speed (feet built per day) was selected as the efficiency metric that would be the response variable is because the literature on mega project management and infrastructure efficiency shows that delays are correlated with cost overruns and completing projects speedily is important for the least disruption possible to society during the construction process; there are also economic benefits to completing a project sooner (Ollivier, Sondhi and Zhou 2014, 8).

Understanding which countries are faster at completing major infrastructure projects and which factors contribute to this outcome is of importance to policy makers and state governments. When a major infrastructure bill is signed, this energizes the whole ecosystem of suppliers and equipment makers in the infrastructure value chain. For example, the Chinese government was able to unlock efficiencies through its commitment to the high speed rail way project. Businesses felt comfortable making large scale investments and innovating, enabled by the certainty and scale of the Chinese government's infrastructure pipeline, which helped increase the efficiency of the whole ecosystem and reduce costs (He, Xu, Wang and Chan 2020, 7). Understanding which factors contribute to the speed, quality and cost of infrastructure is topical in the United States right now, as American Jobs Plan, otherwise known as "Biden's $2 Trillion Infrastructure Bill" was recently proposed and is currently being debated. Federal governments are already taking important steps to increase the efficiency and decrease the timeline for major infrastructure projects. For example, through the Massachusetts Accelerated Bridge Program Legislation, techniques such as the use of prefabricated bridge elements or off site construction and consequent on site installation are being employed (Bridge Masters 2018). However, the rhetoric that surrounds the infrastructure conversation in the U.S. suggests that there is still significant ground that the U.S. needs to cover in order to catch up with the infrastructure quality and speed of countries like China.

This sentiment has been echoed broadly in politics. In a speech to a joint session of congress in September 2011, Obama said "building a world-class transportation system is part of what made us an economic superpower (…) and now we're going to sit back and watch China build newer airports and faster railroads?" (Richburg 2011). In a 2016 rally, Donald Trump was heard saying "they have bridges that are so incredible" about Chinese infrastructure (Areddy 2021). Most recently, President Biden's American Jobs Plan was announced as a plan to "create millions of good jobs, rebuild our country's infrastructure, and position the United States to out-compete China" (Fact Sheet: American Jobs Plan 2021). Some notable differences among the two countries are percentage of GDP invested in infrastructure, how much importance is given to local impact studies and immediately affected residents (Areddy 2021). Furthermore, according to the figures from Council of Foreign Relations, the U.S. spends 2.4 percent of its GDP in infrastructure, compared 8 percent in China (Areddy 2021). It is estimated that this figure is close to 5 percent for European countries, and the state of infrastructure in the U.S. compared to other parts of the world is frequently attributed to the difference in infrastructure funding (McBride and Siripurapu 2021). While this study does not arrive at the same numbers for these figures due to the methodology used, the relative magnitude is comparable (as discussed further on page 15).

Figure 1. G20 Infrastructure Spending by 2040 (as a percentage of GDP)[1]



[1] https://www.cfr.org/backgrounder/state-us-infrastructure

The first goal of the recent infrastructure proposal is to “fix highways, rebuild bridges, upgrade ports, airports and transit systems” (Fact Sheet: American Jobs Plan 2021). This entails renovating ten of the most economically consequential bridges in the country, repairing 10,000 of the smaller bridges that are in worst condition and modernizing 20,000 miles of roads and highways as well as expanding rail into communities that don’t currently have access to it (Fact Sheet: American Jobs Plan 2021). Whatever the total sum of money allocated to infrastructure in the final bill that is passed will be, the largest portion will likely go to transportation infrastructure, as The U.S. Government Accountability Office has found that about one in four bridges are deficient and “10 percent are categorized as structurally deficient and 14 percent categorized as functionally obsolete” (U.S. Government Accountability Office 2015).

Another dimension of efficiency is cost. Cost overruns, and which factors contribute to higher costs in infrastructure projects has been widely discussed in the literature, while construction completion times have not been. A study by the Brookings Institute that only focuses on the U.S. has found that after adjusting for inflation, the cost of building a mile of superhighway in the 1960s had increased by three fold by the 1980s (Brooks and Liscow 2019, 3). Their conclusion for the increase in building costs is due to the demand for more advanced highways, the increase in real estate values and the increased importance that “citizen voice” has in government decision making, as highway features that arise due to local citizen concerns often make the construction more expensive (Brooks and Liscow 2019, 25). In line with the explanations of this paper, there is also a theory explaining the rising cost of construction with land use policies that allow landowners to block construction (Smith 2020).

The data set of the longest bridges in the world was sourced from Wikipedia. Factors previously discussed motivated the hypotheses of this paper, and led to the eventual selection of potential explanatory variables. While this study is a general investigation of whether infrastructure completion times are significantly different among countries and exploration of which, if any, of the variables among those investigated (length, start date, feet built per day, type of traffic, proxy for percentage of GDP invested in infrastructure, GDP per capita, proxy for infrastructure quality, proxy for property rights and rule of law, and binary indicator variables for different regions as well as whether a country is China versus not) are significant predictor variables in explaining feet built per day.

Data was analyzed using Ordinary Least Squares (OLS) regression models and Analysis of Variance (ANOVA). Results indicate that when controlled for a certain bridge's length, start date of construction, level of property rights, and GDP Per Capita of the country the bridge is located in taken at the construction end date, there is no meaningful difference between countries' abilities to complete major infrastructure projects. This can be interpreted as to say that the difference in construction speed is not attributable to which country or region a bridge is located in, but it arises due to different levels of the previously mentioned variables. It was found that a more recent start date, greater bridge length, and stronger property rights are positively correlated with completion speed of a bridge and GDP per capita, thus level of development, is negatively correlated.

1.2. Background : The Need for and Purpose of Infrastructure

Building and renovating infrastructure quickly is a key need for the U.S., as it has poor bridge infrastructure – 33.2 percent of bridges in California and 58.9 percent in New York State are deficient according to the American Society of Civil Engineers. Furthermore, McKinsey Global Institute has estimated that the world needs to invest $3.3 trillion in infrastructure annually to keep pace with projected economic growth (Woetzel, Garemo, Mischke, Hjerpe, and Palter 2016, 2) . This has been coined as the “infrastructure gap” and the sum is distributed among roads, bridges, railways, ports, water infrastructure and telecommunications (Woetzel et al. 2016, 4). However, there is also an argument to be made on the opposite side of the spectrum. Some scholars, such as Henry, Blair and Gardner take an alternative approach to defining the infrastructure investment gap (2019). In their dual hurdle rate framework, they compare a poor country’s social rate of return on infrastructure investment with a rich country’s average return on private capital and the poor country’s return on private capital. They conclude that more investment in a poor country’s infrastructure is “efficient only if the return on poor- country infrastructure exceeds the return on poor-country private capital; and if financeable through private rich-country savings only if the return on poor-country infrastructure exceeds the return on rich-country private capital” (Henry, Blair and Gardner 2019, 8). The authors argue that the $3.3 trillion figure cited by McKinsey doesn’t acknowledge the fact that the differential between scheduled and said to be needed infrastructure is an “equilibrium of the interactions between savers and investors given the opportunities and incentives they face” and that it is important to take into account the data on return on capital of what the market demands and whether the demand is met (Henry et al. 2019, 3). It also seems intuitive that investment in infrastructure would boost GDP growth; however, empirical studies have produced mixed results regarding this, with some studies even concluding a negative elasticity of output with respect to infrastructure investment. One influential study by Caldéron, Moral-Benito and Servén has concluded that the “long-run elasticity of output with respect to the synthetic infrastructure index ranges between 0.07 and 0.10” and that heterogeneity is neither conditional nor unconditional on a country’s level of development, population size or infrastructure endowments (2011, 4).

There is yet another alternative view point arguing that "infrastructure costs should be weighted in favor of broad societal benefits, rather than strict revenue projections" (Areddy 2021). For example, China has historically turned to infrastructure in recessions, using massive investments in infrastructure to spur growth (Richburg 2011). Some argue that the U.S. should take a similar approach and weigh infrastructure costs against its benefits to society, which is in line with what has been outlined in the American Jobs plan (Areddy 2021).

It is important to note that some believe that China's spending on infrastructure in the last years has been excessive, and that it has been ahead of demand and ahead of economic development - this figure is only expected to increase with China's COVID – 19 recovery plans (Richburg 2011).

1.3.Literature Review

A comprehensive study that concludes whether or not some countries are faster at building large infrastructure, specifically, bridges and one that isolates the key factors that contribute to bridge completion speed with a cross-country focus was not found as part of the literature review. This study aims to fill this gap.

When bridge costs are estimated, the variables used are : usable area (total length multiplied by usable width), length of structure span, height of structure above base level, structural system considerations, properties and amount of materials used, country of construction (in terms of cost of materials and labor), technology (used in the fabrication, transport and erection of bridges), construction methods, year of construction and structural type (Mladjov 2016). The main types of bridges are suspension bridges, cable stayed bridges, self-anchored suspension bridges, suspended ribbon bridges, steel continuous girders, steel cantilevered trusses bridges, steel arch bridges, concrete continuous girders, concrete extra-dosed bridges, and concrete arch bridges. Some studies show that suspension and cable stayed bridges are the most time efficient structures (Mlladjov 2016). Furthermore, there is a correlation between the speed and cost of a bridge, and Chantal and Flyvbjerg found that a 1 year delay in the construction can increase cost overrun by 4.64 percent (2013, 15).

Focusing on efficiently building and repairing bridges is especially important in the United States due to the high percentage of bridges that are structurally deficient or structurally obsolete. 27 percent of all bridges in the U.S. are deficient, while this number is close to 59 percent in New York State (Mladjov 2016). Thus, how efficiently these bridges can be built and repaired emerges as an important consideration. One potential reason, among others, could be that even though the United States is one of the most developed economies, it is the country that spends the least amount of funds on infrastructure research and development among developed countries (Gould, Lemer 1994, 22).

Construction delays are also an important problem that keep projects from being completed on time. Research shows that in some countries like the UAE, 50 percent of projects are not completed on time, while 40 percent of projects in India are behind schedule, with the delay ranging from 1 to 252 months (Faridi,Shakeel and El Sayegh 2006, 2 and Iyer and Jha 2006, 1). The leading causes of such delays were shown to be the lengthy process associated with the approval of drawings, slowness of decision making and shortage of manpower (Faridi et al. 2006, 4). A literature review of key studies in this field has identified 11 driving factors that contribute to successful megaproject construction management, namely : “government support, public support, accumulation and application of technology and experience, development and innovation of technology, innovation and application of management systems, organizational mode and structures, top management support, project culture, megaproject citizenship behavior, corporate reputation, and fulfillment of social responsibilities" (He et al. 2020 , 1). One of the most important variables was found to be support from the government and public, with respectively 90 percent and 80 percent of experts surveyed sharing this opinion (He et al. 2020, 6). In developing countries especially, the proper use of contemporary technologies, such as Building Information Modelling (BIM) is proven to increase efficiency (Bui 2020, 3).

In the context of Public-Private Partnerships (P3), it was observed that a stable political system, predictable and reasonable legal framework, predictable currency exchange risk, a favorable economic system, and adequate financial markets were observed to be variables that contribute to project success (Zhang 2005, 8). It was also found that conflict among participants, hostile social environment and harsh climatic conditions are among the top factors that lead to schedule performance failure (Iyer and Jha 2006, 875 - 879).

While it is common to define the completion time of an infrastructure asset as the period from the decision being taken until the construction has ended and operations have begun, the Comission of the European Union has observed that there is an inherent sluggishness in the "preparation, planning, authorization and evaluation procedures for large infrastructure projects", and that the lengthiness of these processes could translate into cost escalation (Flyvbjerg, Holm and Buhl 2004, 7). It is observed that long delays in projects can cause an "interest trap", a situation in which increasing construction costs, delays in paying interest, and increasing interest payments result in a condition in which income from a project is unable to cover its costs (Flyvbjerg et al. 2004, 10). This situation arose in " two longest underwater rail tunnels in Europe, the Channel Tunnel and the Danish Great Belt rail link, which both had to be financially reorganized" (Flyvbjerg et al. 2004, 11).

Methods employed in the literature vary from questionnaires for the more qualitative causal data, such as in Faridi et al. (2006) to statistical analysis of quantitative data collected on bridges in Flyvbjerg et al.(2004) and Mladjov (2016) to case studies used by He et al. (2020) and Bui (2020).

It is notable to point out China's efficient bridge construction systems as well as its history of innovation in this field. Chinese – made bridges both within China, as well as the bridges that Chinese firms built in other countries, have been consistently ranked among the top (Zhou and Zhang 2019, 1). Upon a review of the current literature, if was found that there are many studies that focus on efficiency of bridge structures from a cost angle, but little to none that take speed as the key variable of interest. However, cost and time to completion are shown to be correlated. Based on a survey of the literature, it seems like there are clear winners in terms of the countries that are good at building bridges in a timely and cost effective manner, and some variables that are of importance to completion speed and cost are climate, political and societal support, length, type of bridge and technology.

2. Data and Methodology

2.1.Data Sources

The first data set employed by this paper is the "List of Longest Bridges" [2] on Wikipedia. This data set is split into the bridges that have been completed (n = 257) as well as those that are still in construction (n = 21). It details the length (ft), main span (ft) (longest span without any ground support), year completed, traffic type and country of each bridge.

[2] https://en.wikipedia.org/wiki/List_of_longest_bridges

The data set ultimately used for the analysis presented in this study looks at various attributes of the bridges listed in the Wikipedia data set. Variables of interest for each bridge were length (ft), year completed, country, start date, type of traffic on the bridge, and years to completion (which was found by subtracting the start year from the completion year). For each bridge – country pair in the dataset, GDP at construction end, Gross Fixed Capital Formation, a proxy for percentage of GDP invested in infrastructure, GDP per Capita, World Bank Quality of Overall Infrastructure Index[3] ("infrastructure quality") , and the Property Rights[4] ("property rights") index within World Economic Forum's Global Competitiveness Index were also collected.

For the bridges that had not been completed yet, this study used estimated end dates sourced from Wikipedia or the Web.

While construction end dates were presented in the Wikipedia data set used, construction start date for each bridge was collected through various resources via a Web search. Start dates for some bridges were unavailable, and it was noted that this was the case most frequently for bridges that were older (built before 1960's) or bridges that were located in China.

There are challenges with reporting and choosing start dates. For most of the data collected, the start date did not have a definition and it was only presented in year format. Because month – level data was unavailable, this explanatory variable lacked granularity. Furthermore, the start date could be defined as when the project was approved, when construction physically began or the scheduled start date. For the purposes of this analysis, it is assumed that start date means the date at which the physical construction of a bridge started; however, there is no assurance that

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3 https://tcdata360.worldbank.org/indicators/h2cf9f9f8?country=BRA&indicator=535&viz=line_chart&years=2007,2017

4 https://govdata360.worldbank.org/indicators/hc8535f2d?country=BRA&indicator=41351&viz=line_chart&years=2017,2019

the corresponding data belongs to this date, as this data was not available. There are similar concerns for the construction completion date which could mean the day on which a bridge is opened to the public, the day when physical construction ends or is scheduled to end.

In order to get a proxy for percentage of GDP invested in infrastructure, this study used a ratio of Public Gross Fixed Capital Formation (GFCF) to GDP for the country a bridge was located in. Both measures were reported in billions of constant 2011 international Dollars and taken at the year the construction for that particular bridge ended. This analysis chose to use ending dates for the infrastructure project analyzed because data was not readily available in the same units (constant 2011 international Dollars) for years before 1960 and some of the bridges analyzed had a start date well before 1960.

However, because of this approach, the data set had GDP estimates for the estimated completion years of the uncompleted bridge structures.

The GDP at construction end and GFCF for each country and year was sourced from the "Investment and Capital Stock Dataset, 1960 – 2015" published by the International Monetary Fund Fiscal Affairs Department. For years beyond 2015, the missing data for GFCF as a percentage of GDP was filled by using World Bank's national accounts data and OECD national accounts data files available through the Web. Note that the variable of interest is GFCF as a percentage of GDP (used as a proxy for percentage of GDP invested in infrastructure), and GDP and GFCF are intermediary steps to arrive at the aforementioned ratio.

For bridges that had not been completed yet, the proxy for percentage of GDP invested in infrastructure in the construction completion year was taken from the most recent available data (2019 in most cases).

There were a few ways in which a proxy for percentage of GDP invested in infrastructure could be computed. Fay, Lee, Mastruzzi, Han and Cho (2019) propose three main methodologies.

The first proposition is using GFCF of general government, as well as World Bank's Private Participation in Infrastructure (PPI) data set. GFCF is available for most countries in a time series format for the years 1960 - 2015. One major drawback of this method is that it excludes investment from State Owned Enterprises which have an important role in the transportation sector (Fay et al. 2019 , 12). Double counting could also be an issue given that the PPI database also includes public-private partnerships (Fay et al. 2019, 13).

Another approach would be to use the International Comparison Program database of World Bank, which has data on GFCF excluding buildings (Fay et al. 2019, 14). However, this methodology would not be appropriate for the purposes of this analysis, as it only has data available for a few years, and is not presented in time series format like GFCF and PPI.

Alternatively, the BOOST data set could be utilized to capture infrastructure spending. The BOOST initiative was undertaken by the World Bank, and it has budget and public expenditure data for a number of countries. However, the executed budget would need to be extracted from this data, and smoothed to produce an annual average (Fay et al. 2019, 15). Also, the BOOST database only includes 55 countries, so using it for the purposes of this analysis would have been challenging (Fay et al. 2019, 16)

While using the sum of GFCF and PPI to get a proxy for money spent on infrastructure would have been optimal, there were some data challenges. The PPI data required data cleaning to isolate private share for Public – Private Partnerships, and since data is presented on a project level, it is difficult to tag it to the countries and years in which the expenditure occurred.

Furthermore, the PPI data is only available after 1984, while the GFCF data dates back to 1960. To ensure consistency in what would be a proxy for how much money is invested in infrastructure in a given year, as well as for the previously discussed reasons, GFCF was used. Percent of GDP invested in infrastructure was estimated through the ratio of GFCF to GDP. It is not a precise estimate of infrastructure because it includes sectors other than infrastructure such as health and mining (Fay et al. 2019, 7). This measure could over estimate or under estimate the actual percent of GDP invested in infrastructure based on the relative share of public investment in non – infrastructure sectors, as well as the role of private investment in infrastructure (Fay et al. 2019, 15).

GDP per capita was sourced from World Bank's data set that measures GDP per capita in current U.S. Dollars for all countries and years 1960 – 2019. This was taken at the year the construction of the bridge ended (similarly to percent of GDP invested in infrastructure) for consistency.

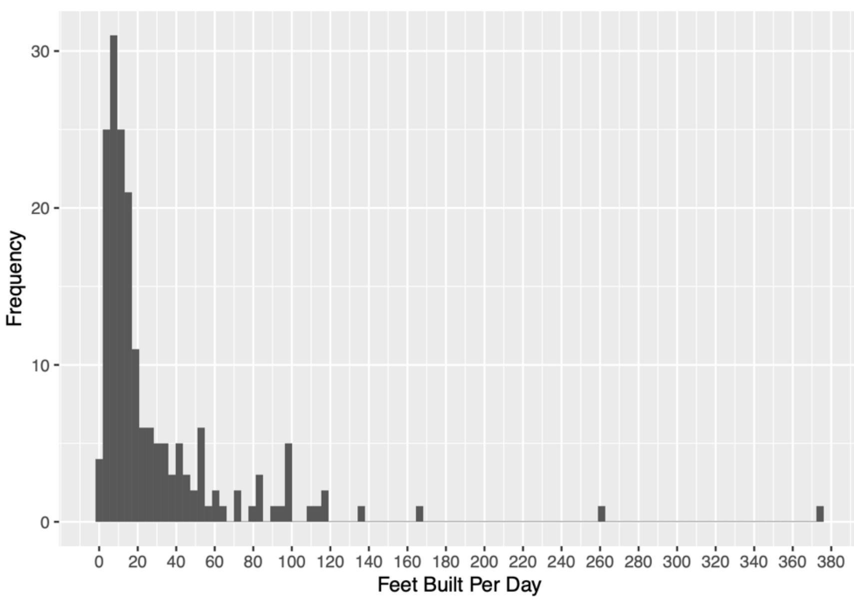
2.2.Methodology

While the initial data set on Wikipedia had 278 bridges, the final data set employed in the analysis had 184 bridges because of bridges that had missing data, which were removed. If a particular bridge was missing any of the years to completion, percent of GDP invested in infrastructure, length, type of traffic, country, World Bank Quality of Infrastructure Index, World Economic Forum's Property Rights Index, then that data point was not used in the analysis.

This study uses a quantitative approach to understand which factors lead to faster completion times in bridge infrastructure projects. To this end, five regression analyses were conducted.

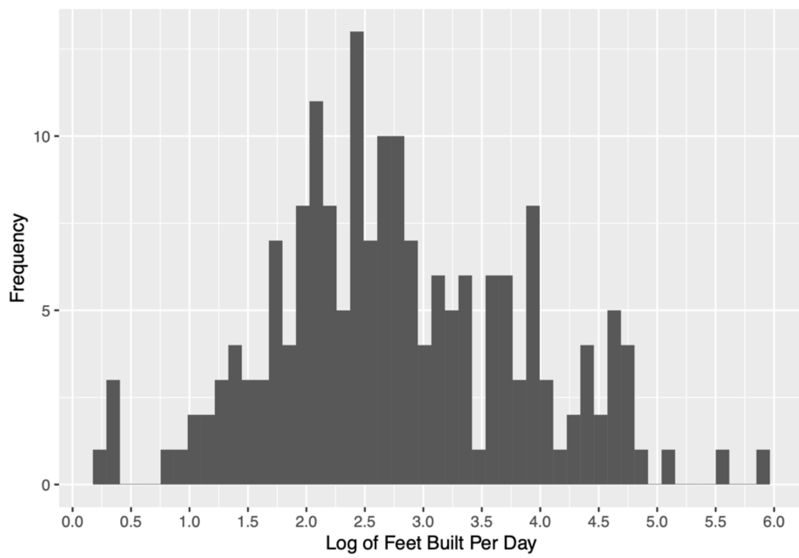
For purposes of regression, the regions and traffic types were coded as binary variables ("region dummy" and "traffic dummy"). Furthermore, a dummy for whether a particular bridge is located in China was included ("China dummy"). The response variable is feet built per day for the bridges analyzed, which was found by dividing the length of the bridge by completion time in years multiplied by 360. Because of the skewness in feet built per day (as shown in Figure 2), the logarithm of this measure was used to conduct the analysis.

Figure 2. Histogram of Feet Built Per Day



Taking the logarithm of feet built per day reduces the skewness of the response variable, as shown in Figure 3.

Figure 3. Histogram of Log (Feet Built Per Day)



2.2.1. Regressions

Model 1

This analysis involves regressing log (feet per day) over length in feet, construction start date, percentage of GDP invested in infrastructure, property rights, infrastructure quality, GDP per capita, and the China and traffic dummies. Using a p – value cut off of 0.05, the resulting regression equation that only contains the significant variables is :

$$Log\ (feet\ built\ per\ day) = -36.83 + 0.000009808 * Length$$
$$+0.01851 * Start\ Date - 0.00001998 * GDP\ per\ Capita \tag{1}$$

The residual standard error is 0.7374 and the adjusted R squared is 0.5247.

Figure 4. Regression Coefficients of Model 1[5]

Characteristic	Beta	95% CI	p-value
country_dummy	0.31	-0.42, 1.0	0.4
length.ft	0.00	0.00, 0.00	<0.001
start	0.02	0.01, 0.03	<0.001
percentage	-1.7	-7.1, 3.7	0.5
rights	0.19	-0.15, 0.53	0.3
quality	0.13	-0.07, 0.33	0.2
gdp.capita	0.00	0.00, 0.00	<0.001
HSR	0.73	-0.83, 2.3	0.4
HW	0.71	-0.82, 2.2	0.4
MT	0.90	-0.66, 2.5	0.3
EXPW	0.64	-0.89, 2.2	0.4
EXPWR	0.66	-1.1, 2.5	0.5
RD	0.36	-1.2, 1.9	0.6
RM	-1.3	-3.4, 0.85	0.2
RR	0.91	-0.69, 2.5	0.3
ROR	-0.03	-1.6, 1.6	>0.9
HWR	0.29	-1.3, 1.9	0.7
MTWY	0.77	-0.84, 2.4	0.3
MG	1.9	-0.21, 4.0	0.077
EBRT	2.0	-0.11, 4.1	0.063

It is observed that holding other factors constant, a more recent construction start date and a greater bridge length result in higher construction speed, while a larger GDP per capita is negatively correlated with construction speed, as measured by feet built per day.

The relationship of length with feet built per day could be interpreted in a few ways. While it might be intuitive to think that longer bridges require more complex techniques, which could decrease the construction speed, it is also logical to think that countries that are better and faster at building bridges build longer bridges, hence resulting in length having a positive correlation with feet built per day. However, these are conclusions that cannot be reached solely with this data, and would have to be further investigated.

Start date being positively correlated with feet built per day shows that for the newer bridges in the data set, it took less time to build a feet of the structure compared to older bridges,

[5] The regression coefficients presented in this table are rounded, whereas the raw forms are presented in Equation 1

holding all other factors constant. This could suggest that countries, on average, have become more efficient at building bridges over time. It is likely that length and start date have high collinearity, which could be a concern in the interpretation of these results.

GDP per capita is an indicator of development. The fact that it is negatively correlated with feet built per day indicates that, on average, the more "developed" countries were slower at building bridges compared to the emerging ones. Given that GDP per capita has had an increasing time trend for most countries over history, it is an interesting conclusion to see that while GDP per capita and time (manifested as start date here) are highly positively correlated, and start date has a positive correlation with feet built per day, it has a negative correlation with GDP per capita.

Model 2

This analysis involves regressing log (feet per day) over length in feet, construction start date, percentage of GDP invested in infrastructure, property rights, infrastructure quality, GDP per capita, and the region, China and traffic dummies. Using a p – value cut off of 0.05, the resulting regression equation that only contains the significant variables is :

$$Log\ (feet\ built\ per\ day) = -57.11 + 0.000009637 * Length$$
$$+0.02872 * Start\ Date + 0.3644 * Property\ Rights - 0.00002783 * GDP\ per\ Capita$$
$$+\ 2.109\ Elevated\ Bus\ Rapid\ Transit \tag{2}$$

Figure 5. Regression Coefficients of Model 2 [6]

Characteristic	Beta	95% CI	p-value
length.ft	0.00	0.00, 0.00	<0.001
start	0.03	0.02, 0.04	<0.001
percentage	1.7	-3.9, 7.3	0.6
rights	0.36	-0.01, 0.74	0.055
quality	0.04	-0.19, 0.26	0.7
gdp.capita	0.00	0.00, 0.00	<0.001
APAC	-0.36	-1.5, 0.74	0.5
NAM	0.45	-0.73, 1.6	0.5
ME	-0.10	-1.4, 1.2	0.9
LATAM	0.09	-1.1, 1.2	0.9
EU	0.22	-0.92, 1.4	0.7
HSR	0.68	-0.84, 2.2	0.4
HW	0.51	-1.0, 2.0	0.5
MT	1.0	-0.56, 2.5	0.2
EXPW	0.64	-0.85, 2.1	0.4
EXPWR	0.62	-1.1, 2.4	0.5
RD	0.36	-1.1, 1.8	0.6
RM	-1.4	-3.5, 0.73	0.2
RR	0.93	-0.63, 2.5	0.2
ROR	-0.01	-1.6, 1.6	>0.9
HWR	0.48	-1.1, 2.1	0.5
MTWY	0.84	-0.74, 2.4	0.3
MG	1.8	-0.28, 3.8	0.090
EBRT	2.1	0.06, 4.2	0.044
country_dummy	0.08	-0.64, 0.81	0.8

The residual standard error is 0.7194 and the adjusted R squared is 0.5476.

Model 2 is the most informative, since it controls for the most variables. When all of the dummies are included, "EBRT" which stands for Elevated Bus Rapid Transit and property rights (with a p-value of 0.056, which is slightly above the cut off used for significance in this analysis, but it is included due to its interpretation) becomes significant. This shows that holding all other factors constant, structures that were EBRTs were built faster. Furthermore, it was seen that the property rights and rule of law index also had a significant positive correlation with feet built per day. This means feet built per day is higher in countries that rank high on the property rights and rule of law index. From the countries included in the dataset, Ukraine and Peru were among the countries ranked lowest in this index, whereas Singapore and Japan are among those that are ranked the highest. While it is logical that better property rights and a better legal system promotes the faster building of bridges, one of the reasons as to why the U.S. is sluggish when it comes to completing large infrastructure projects is thought to be the land use policies that allow landowners to block construction, which is a

[6] The regression coefficients presented in this table are rounded, whereas the raw forms are presented in Equation 2

situation that arises when countries have strong judicial systems and property rights, so these two conclusions seem to be contradicting each other (Smith 2020).

Model 3

This analysis involves regressing log (feet per day) over length in feet, construction start date, percentage of GDP invested in infrastructure, property rights, infrastructure quality, GDP per capita, and traffic dummies . Note that this model does not include any geographical information. Using a p – value cut off of 0.05, the resulting regression equation that only contains the significant variables is :

$$Log\ (feet\ built\ per\ day) = -37.26 + 0.00003193 * Length$$
$$+ 0.01842 * Start\ Date - 0.00001939 * GDP\ per\ Capita \tag{3}$$

The residual standard error is 0.7367 and the adjusted R squared is 0.5256

Similar to Model 1, it is observed that holding other factors constant, a more recent construction start date and a greater bridge length result in higher construction speed, while a larger GDP per capita is negatively correlated with construction speed, as measured by feet built per day. The exclusion of the China dummy does not impact the model results or interpretation significantly. Even when whether a country is China or not is not controlled for, length, start date and GDP per capita emerge as the variables with most predictive power.

Figure 6. Regression Coefficients of Model 3 [7]

Characteristic	Beta	95% CI	p-value
length.ft	0.00	0.00, 0.00	<0.001
start	0.02	0.01, 0.03	<0.001
percentage	0.27	-2.6, 3.1	0.8
rights	0.17	-0.17, 0.51	0.3
quality	0.13	-0.07, 0.33	0.2
gdp.capita	0.00	0.00, 0.00	<0.001
HSR	0.68	-0.88, 2.2	0.4
HW	0.58	-0.92, 2.1	0.4
MT	0.77	-0.76, 2.3	0.3
EXPW	0.54	-1.0, 2.0	0.5
EXPWR	0.61	-1.2, 2.4	0.5
RD	0.23	-1.3, 1.7	0.8
RM	-1.4	-3.5, 0.74	0.2
RR	0.80	-0.77, 2.4	0.3
ROR	-0.19	-1.7, 1.4	0.8
HWR	0.23	-1.4, 1.8	0.8
MTWY	0.65	-0.94, 2.2	0.4
MG	1.8	-0.30, 3.8	0.093
EBRT	1.9	-0.19, 4.0	0.074

Model 4

This analysis involves regressing log (feet per day) over length in feet, construction start date, percentage of GDP invested in infrastructure, property rights, infrastructure quality, GDP per capita, and the China and region dummies . Using a p – value cut off of 0.05, the resulting regression equation that only contains the significant variables is :

$$Log\ (feet\ built\ per\ day) = -63.59 + 0.000001069 * Length + 0.03191 * Start\ Date + 0.5025\ Property\ Rights - 0.00003017 * GDP\ per\ Capita \quad (4)$$

[7] The regression coefficients presented in this table are rounded, whereas the raw forms are presented in Equation 3

Figure 7. Regression Coefficients of Model 4[8]

Characteristic	Beta	95% CI	p-value
length.ft	0.00	0.00, 0.00	<0.001
start	0.03	0.02, 0.04	<0.001
percentage	1.1	-4.5, 6.7	0.7
rights	0.50	0.13, 0.87	0.008
quality	0.02	-0.19, 0.24	0.8
gdp.capita	0.00	0.00, 0.00	<0.001
APAC	-0.33	-1.4, 0.79	0.6
NAM	0.44	-0.73, 1.6	0.5
ME	-0.26	-1.6, 1.0	0.7
LATAM	0.15	-1.0, 1.3	0.8
EU	0.15	-1.0, 1.3	0.8
country_dummy	0.24	-0.44, 0.91	0.5

The residual standard error is 0.7512 and the adjusted R squared is 0.5067

Even when the type of traffic is not controlled for, it is observed that holding other factors constant, a more recent construction start date, greater bridge length and better property rights result in higher construction speed, while a larger GDP per capita is negatively correlated with construction speed, as measured by feet built per day. The interpretations of Model 2 are carried through.

Model 5

This analysis involves regressing log (feet per day) versus the country and region dummies.

$$Log\ (feet\ built\ per\ day) = 2.2005 + 0.8017 * China\ (1\ or\ 0) \tag{5}$$

[8] The regression coefficients presented in this table are rounded, whereas the raw forms are presented in Equation 4

When the other variables are not controlled for, it looks as if China has an advantage in construction speed over other countries. However, as the results of Model 2 show, the fact that China has a mean feet per day built that is higher than the other countries in this data set is explained by the bridge's start date, length, the country's GDP per capita, property rights and whether or not a bridge is an EBRT. Furthermore, when an ANOVA is run using the regions as the levels, there is no significant difference between the regions' mean feet built per day (p – value of accompanying F statistic is 0.297)

Figure 8. Regression Coefficients of Model 5[9]

Characteristic	Beta	95% CI	p-value
region			
Africa			
Asia & Pacific	0.46	-1.0, 1.9	0.5
Europe	0.23	-1.3, 1.7	0.8
Middle east	0.55	-1.1, 2.2	0.5
North America	0.46	-1.0, 1.9	0.5
South/Latin America	0.31	-1.3, 1.9	0.7
country_dummy	0.80	0.39, 1.2	<0.001

3. Discussion of Results and Analysis

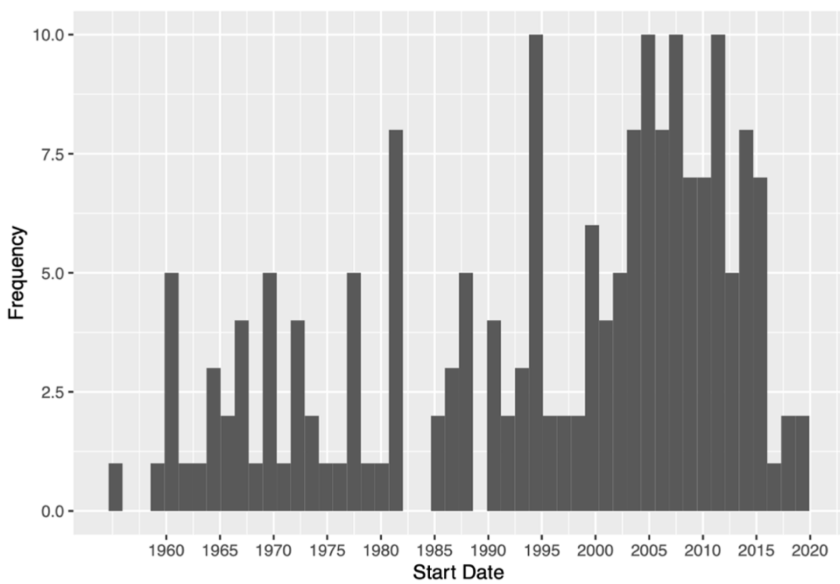
3.1. Descriptive Statistics

The oldest bridge in the data set was the Gardiner Expressway in Canada, which was built in 1955 and the most recent one was the Versova – Bandra Sea Link in India, whose

[9] The regression coefficients presented in this table are rounded, whereas the raw forms are presented in Equation 5

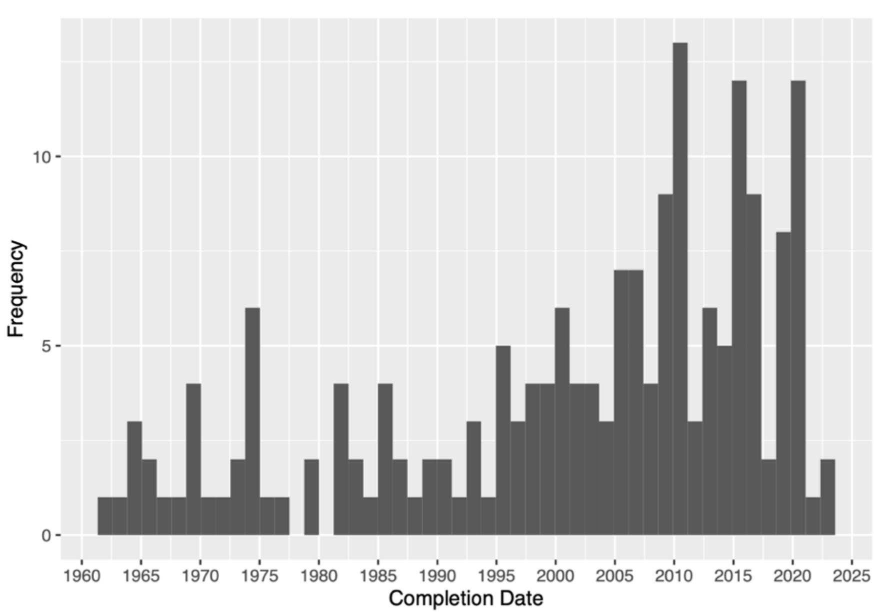
construction started in 2019 and is set to end in 2023. The start date of the bridges in the data set is concentrated around 2004 to 2015, as shown in Figure 9. The average start date was 1995 with a standard deviation of 16.9 years (Tables 1 and 2).

Figure 9. Histogram of Construction Start Date



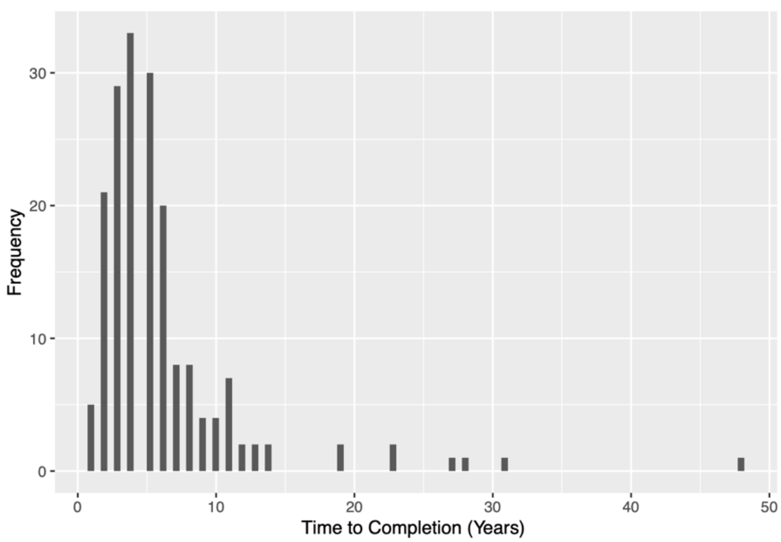
The completion dates of the bridges was centered around 2009 and 2015, as shown in Figure 10. The average completion date was 2001 with a standard deviation of 16.41 years (Tables 1 and 2).

Figure 10. Histogram of Completion Date



The time to completion is concentrated in 2 to 8 years with a mean of 6.04 years and a standard deviation of 5.61 as shown in Figure 11.

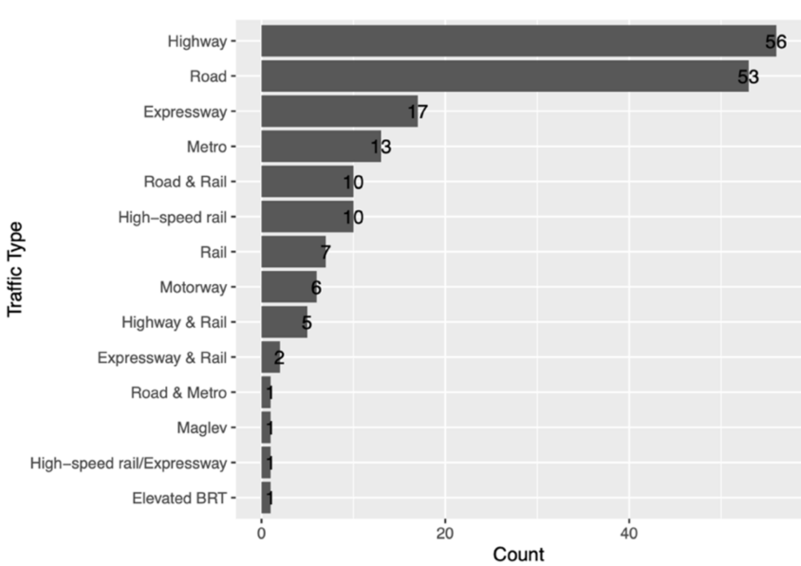
Figure 11. Histogram of Time to Completion



The mean feet built per day is 29.62 and the standard deviation is 42.88; the distribution of feet built per day is shown in Figure 17.

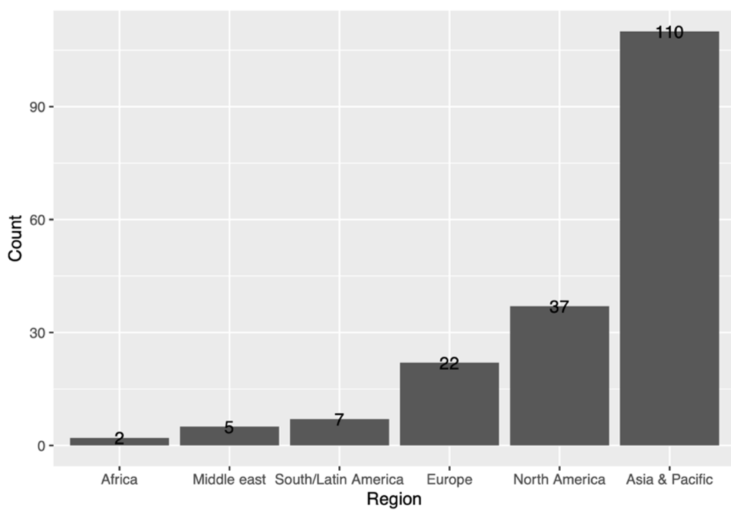
The bridges in the data set are mostly highways (n = 56) and roads (n=53), as shown in Figure 12.

Figure 12. Distribution of Traffic Type



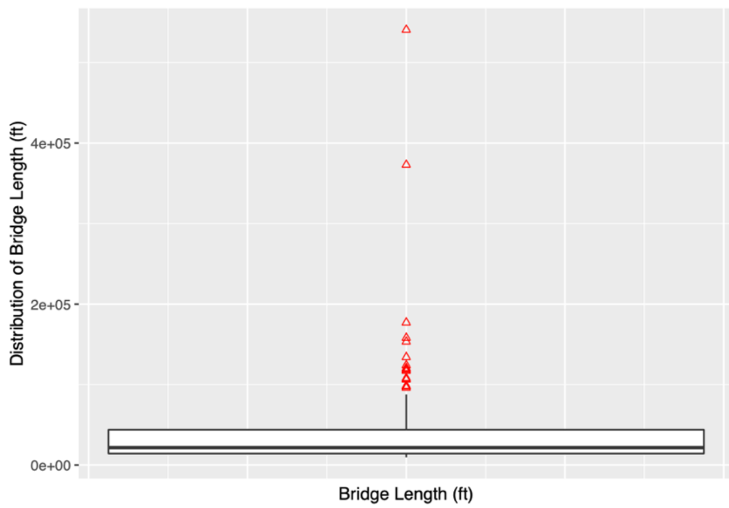
The data is concentrated in the Asia – Pacific Region (n=110), and the distribution of data points across regions can be seen in Figure 13.

Figure 13. Distribution of Data Across Regions



The average length of the bridges in the data set is 41543.44 feet, and the standard deviation is 55922.93 feet as shown in Tables 1 and 2. The longest bridge in the data set is the Danyang Kunshan Grand Bridge, which is 540700 feet long, located in China and was completed in 2010. The shortest bridge in the data set is Jiangyin Bridge, which is 9800 feet is also in China and was completed in 1999. The distribution of the length of the bridges in the data set is shown in Figure 14.

Figure 14. Boxplot of Bridge Length



Percentage of GDP invested in infrastructure had a mean of 7.3 percent and a standard deviation of 5.2 percent (as shown in Tables 1 and 2) . These results proxied by the method discussed previously are likely to be an over estimation given that not all public spending is in infrastructure related sectors. The average percentage of GDP invested in infrastructure in this data set is biased according to which year the data comes from, as it was computed by taking an arithmetic average of the percentage of GDP invested in infrastructure for each bridge, country and completion date combination.

Figure 15. Distribution of Percentage of GDP Invested in Infrastructure Across Regions

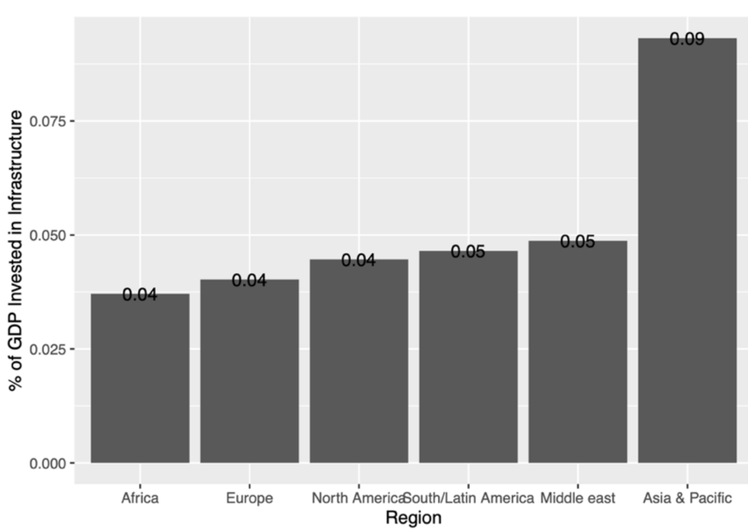
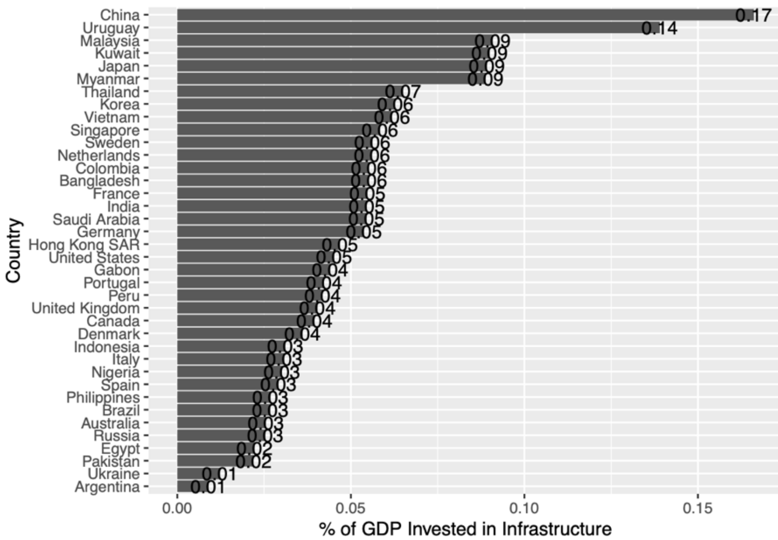


Figure 16. Distribution of Percentage of GDP Invested in Infrastructure Across Countries



Consistent with the data of actual percentage of GDP invested in infrastructure, the methodology employed shows that this figure is highest in the Asia & Pacific region. This is also due to the fact that China is an outlier. One reason why Uruguay's percentage of GDP invested in infrastructure looks high is because this data set only has one bridge that is in Uruguay. The Libertador General San Martin Bridge's construction started in 1972 and ended in 1976. Uruguay had a civic military dictatorship from 1973 to 1985, and the percent of GDP invested in infrastructure figure was calculated for 1976, the year construction ended, for reasons discussed earlier (Civic – Military Dictatorship of Uruguay). As GFCF represents general government investment in non-infrastructure sectors as well, this could be an artificially high data point due to high military spending or large investments made in the public sector with the aim of improving Uruguay's economy that shrunk under Juan Maria Bordaberry's rule (Civic – Military Dictatorship of Uruguay).

Descriptive statistics of key variables are presented in tables one and two.

Table 1: Mean of selected measures

Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property Rights	Feet per Day
41543.44	2001.45	1995.46	6.04	0.07	4.71	4.85	29.62

Table 2: Standard Deviation of selected measures

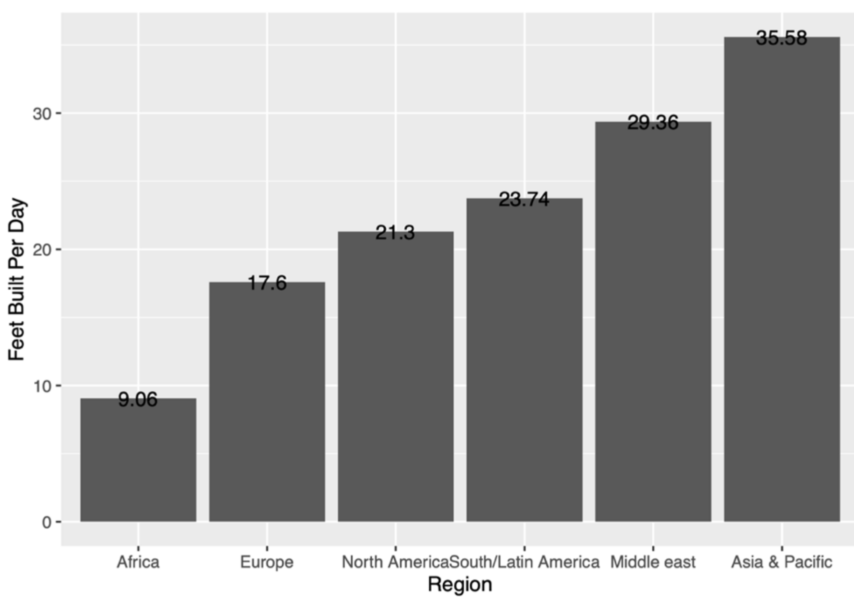
Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property rights	Feet per Day
55922.93	16.41	16.86	5.61	0.05	1.03	0.71	42.88

Length has a large standard deviation, potentially suggesting that some countries are more advanced at building bridges (this conclusion will be further discussed in the following section). Feet built per day also has a large standard deviation, suggesting that either over time, countries have become more efficient from a time perspective at building bridges or that some countries have an advantage when it comes to the speed at which infrastructure projects are completed.

3.2 Discussion of Results and Analysis

The first hypothesis explored is whether some countries or those located in a certain region seem to build bridges faster. Looking at the distribution of feet built per day across regions, it is observed that the Asia & Pacific region is the fastest at completing major infrastructure projects and Africa is the slowest. On average 35.58 feet was built per day in the bridges analyzed in the Asia & Pacific region, 29.36 feet in the Middle East, 23.74 feet in South America, 21.3 feet in North America, 17.6 feet in Europe, and 9.06 feet in Africa. However, as discussed earlier ANOVA shows that there is no significant difference in bridge completion times among countries. It must also be noted that the majority of data in the data set comes from APAC (n = 110) while there are only 2 in Africa, 5 in the Middle East and 7 in South America, purely due to the fact that those regions have less bridges that are in the "Longest Bridges in the World" list, which also is an indicator of countries' ability to produce high quality and modern infrastructure, but could also be a reflection of the differing bridge needs of countries. Also, on average, the bridges in APAC are more recently built, as the average start date is 2002, compared to 1980 in North America.

Figure 17. Feet Built Per Day Across Regions



Region specific key descriptive statistics are presented in tables three and four.

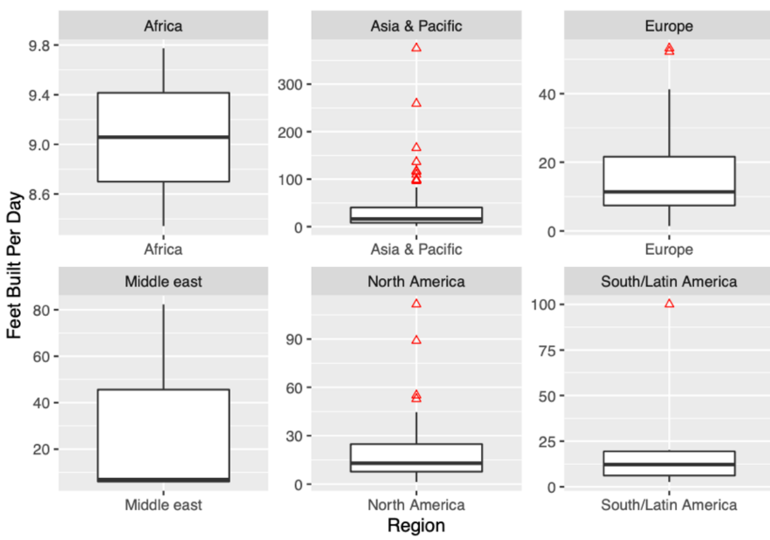
Table 3: Mean of selected measures by region

Region	Number of data points	Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property Rights
Africa	2	26858.00	2005.00	1997.00	8.00	0.04	2.70	3.57
Asia & Pacific	110	50640.81	2008.26	2002.34	5.93	0.09	4.41	4.66
Europe	22	22614.05	1995.23	1988.41	6.82	0.04	5.16	4.86
Middle east	5	58321.60	1996.80	1989.00	9.40	0.05	4.40	5.24
North America	37	25578.70	1986.00	1980.62	5.38	0.04	5.78	5.57
South/Latin America	7	34673.57	1998.00	1992.14	5.86	0.05	3.21	4.04

Table 4: Standard Deviation of selected measures by region

Region	Number of data points	Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property rights
Africa	2	16747.12	19.80	24.04	4.24	0.01	0.54	0.10
Asia & Pacific	110	67631.51	10.97	12.01	4.25	0.06	0.92	0.61
Europe	22	15771.35	18.19	17.37	7.48	0.02	0.89	0.88
Middle east	5	46337.27	12.07	19.13	9.86	0.03	0.47	0.53
North America	37	23853.53	17.40	17.23	7.51	0.01	0.20	0.02
South/Latin America	7	35240.44	18.40	19.07	2.67	0.04	0.18	0.49

Figure 18. Boxplot of Feet Built Per Day Across Regions

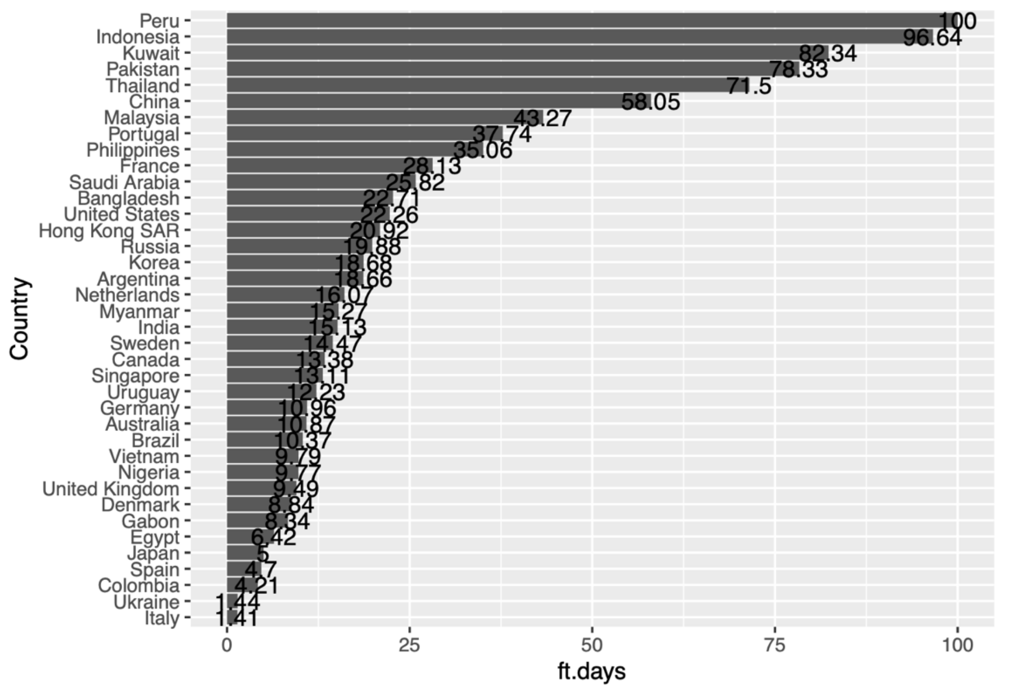


As shown in Figure 18, while the distribution of feet per day is more uniform in the Middle East and Africa, some significant outliers are observed in APAC, Europe, Latin America and North America. One reason for this phenomenon is that as discussed earlier, bridge completion time has increased over time, and the data set of bridges in APAC has newer bridges, whereas that is not the case for the other regions (mean start dates of 1988, 1980 and 1992 for Europe, North America, and South America, respectively).

When the outliers are analyzed, it is found that the most significant outlier in the APAC region is the Danyang Kunshan Grand Bridge located in China. It is the longest bridge in the world (102.4 miles), the construction took 4 years, employed 10,000 people and cost $8.5 billion (Danyang – Kunshan grand bridge). Some of the outliers in Europe include Leziria Bridge located in Portugal, 38290 feet long, started in 2005 and took 2 years to complete ; and the Vasco de Gama Bridge, located in Portugal, 56381 feet long, started in 1995 and took 3 years to complete. In North America, a significant outlier is the Manchac Swamp Bridge, located in the U.S. , 120440 feet long, started in 1976 and took 3 years to complete, as well as the Atchafalaya Basin Bridge, located in the U.S. , 96100 feet long, started in 1970 and took 3 years to complete. In South America, the most significant outlier is the Lima Metro, located in Peru, 108000 feet long, and although construction started earlier, most of it was completed between 2011 and 2014.

While Peru, Indonesia, Kuwait, Pakistan and Thailand have high “feet built per day” measures for their bridges that are included in this data set (as shown in Figure 19), the data is biased due to the low number of bridges in the data set that belong to these countries. For example, the Lima Metro, as previously discussed, was built in chunks over a number of years due to delays, but as most of it was built between 2011 and 2014, the time to completion was taken as three years. As a result of this, feet built per day is artificially high. Indonesia only has three data points in the data set, while Kuwait and Pakistan have one, and Thailand has two. China on the other hand, while appearing to be the 6th fastest country in terms of feet built per day, has 37 bridges in this data set. So, while it is immature based on the limited amount of data to say that the first five countries ranked highest in terms of feet per day have an advantage in building bridges fast, this conclusion can be drawn for China.

Figure 19. Feet Per Day Across Countries



Country level means and standard deviations for the key variables are provided in Tables 5 and 6.

Table 5: Mean of selected measures by country

Country	Number of data points	Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property Rights
Argentina	1	40295.00	2003.00	1997.00	6.00	0.01	3.25	3.75
Australia	4	14169.50	2011.25	2007.50	3.75	0.03	4.70	6.07
Bangladesh	10	42719.00	2016.40	2010.00	6.40	0.06	2.91	3.96
Brazil	3	22065.00	1991.33	1984.33	7.00	0.03	3.14	3.93
Canada	4	26851.25	1985.25	1968.75	16.50	0.04	5.21	5.63
China	37	75162.19	2006.03	2001.30	4.73	0.17	4.53	4.58
Colombia	1	10620.00	2019.00	2012.00	7.00	0.06	3.11	4.08
Denmark	1	22280.00	1998.00	1991.00	7.00	0.04	5.83	6.00
Egypt	2	40050.00	1998.50	1982.00	16.50	0.02	4.02	5.14
France	2	35005.00	1971.50	1968.50	3.00	0.05	6.05	5.22
Gabon	1	15016.00	2019.00	2014.00	5.00	0.04	3.08	3.50
Germany	2	13450.00	1974.00	1970.50	3.50	0.05	5.72	5.31
Hong Kong SAR	2	18096.00	1994.50	1992.00	2.50	0.05	6.35	4.58
India	23	30796.22	2013.13	2006.09	7.04	0.05	4.56	4.46
Indonesia	3	59647.00	2013.00	2010.00	3.00	0.03	4.13	4.69
Italy	1	11703.00	1995.00	1972.00	23.00	0.03	4.28	4.38
Japan	5	19137.40	1995.20	1981.40	13.80	0.09	6.20	6.21
Korea	4	33240.00	2002.75	1996.75	6.00	0.06	5.65	5.02
Kuwait	1	118570.00	2015.00	2019.00	4.00	0.09	4.13	4.44
Malaysia	4	65275.00	2008.50	2003.75	4.75	0.09	5.31	5.51
Myanmar	3	20919.67	2009.00	2003.00	6.00	0.09	2.42	4.02
Netherlands	2	18238.00	1985.50	1981.50	4.00	0.06	6.23	6.09
Nigeria	1	38700.00	1991.00	1980.00	11.00	0.03	2.32	3.64
Pakistan	1	28200.00	2015.00	2014.00	1.00	0.02	3.79	4.05
Peru	1	108000.00	2014.00	2011.00	3.00	0.04	3.09	3.55
Philippines	6	61265.00	2003.83	1997.67	6.17	0.03	2.96	4.49
Portugal	3	36257.00	2001.67	1998.33	3.33	0.04	5.69	4.92
Russia	5	23160.20	2012.20	2005.20	7.00	0.03	3.98	3.68
Saudi Arabia	2	46469.00	1986.00	1981.00	5.00	0.05	4.92	5.73
Singapore	2	62150.00	2001.50	1988.00	13.50	0.06	6.42	6.37
Spain	1	10144.00	2015.00	2009.00	6.00	0.03	5.51	4.78
Sweden	2	22829.50	1985.50	1981.00	4.50	0.06	5.63	5.52
Thailand	2	128700.00	2005.00	2000.00	5.00	0.07	4.13	4.33
Ukraine	1	14541.00	2021.00	1993.00	28.00	0.01	3.62	3.32
United Kingdom	2	17612.00	1983.50	1978.00	5.50	0.04	4.99	5.50
United States	33	25424.45	1986.09	1982.06	4.03	0.05	5.85	5.56
Uruguay	1	17605.00	1976.00	1972.00	4.00	0.14	3.59	5.08
Vietnam	4	13044.50	2012.00	2007.75	4.25	0.06	3.59	3.99

Table 6: Standard Deviation of selected measures by country

Country	Number of data points	Length	End	Start	Years	GDP Invested in Infrastructure	WB Quality	Property rights
Argentina	1	NA	NA	NA	NA	NA	NA	NA
Australia	4	2533.35	8.58	7.90	0.96	0.00	0	0.00
Bangladesh	10	42688.29	7.29	9.19	3.89	0.01	0	0.00
Brazil	3	18656.49	18.61	20.26	3.61	0.01	0	0.00
Canada	4	10580.26	25.09	16.90	21.30	0.01	0	0.00
China	37	101803.07	10.31	11.25	3.34	0.02	0	0.00
Colombia	1	NA	NA	NA	NA	NA	NA	NA
Denmark	1	NA	NA	NA	NA	NA	NA	NA
Egypt	2	38537.32	3.54	18.38	14.85	0.00	0	0.00
France	2	33934.05	3.54	4.95	1.41	0.01	0	0.00
Gabon	1	NA	NA	NA	NA	NA	NA	NA
Germany	2	735.39	0.00	0.71	0.71	0.00	0	0.00
Hong Kong SAR	2	135.76	16.26	15.56	0.71	0.03	0	0.00
India	23	25702.49	10.01	10.66	3.17	0.02	0	0.22
Indonesia	3	53104.88	4.00	6.24	2.65	0.00	0	0.00
Italy	1	NA	NA	NA	NA	NA	NA	NA
Japan	5	13361.54	4.44	9.58	9.73	0.01	0	0.00
Korea	4	25018.36	4.27	5.56	1.83	0.00	0	0.00
Kuwait	1	NA	NA	NA	NA	NA	NA	NA
Malaysia	4	15809.57	15.67	14.66	2.36	0.00	0	0.00
Myanmar	3	604.47	3.46	5.20	4.58	0.04	0	0.06
Netherlands	2	2491.84	28.99	26.16	2.83	0.02	0	0.00
Nigeria	1	NA	NA	NA	NA	NA	NA	NA
Pakistan	1	NA	NA	NA	NA	NA	NA	NA
Peru	1	NA	NA	NA	NA	NA	NA	NA
Philippines	6	47477.82	19.24	17.44	3.54	0.01	0	0.00
Portugal	3	21213.69	4.73	5.77	1.53	0.01	0	0.00
Russia	5	20516.98	4.09	11.12	9.03	0.00	0	0.00
Saudi Arabia	2	50248.42	0.00	0.00	0.00	0.00	0	0.00
Singapore	2	31324.83	7.78	0.00	7.78	0.03	0	0.00
Spain	1	NA	NA	NA	NA	NA	NA	NA
Sweden	2	4113.24	19.09	19.80	0.71	0.02	0	0.00
Thailand	2	68306.52	7.07	7.07	0.00	0.01	0	0.00
Ukraine	1	NA	NA	NA	NA	NA	NA	NA
United Kingdom	2	1114.40	17.68	19.80	2.12	0.03	0	0.00
United States	33	25087.71	16.78	16.96	1.91	0.01	0	0.00
Uruguay	1	NA	NA	NA	NA	NA	NA	NA
Vietnam	4	3337.79	4.69	5.32	1.50	0.00	0	0.00

4. Conclusion and Further Considerations

4.1. Conclusion

The data points to the conclusion that some countries complete bridges faster, and length of the bridge, start date of the bridge and strong property rights increase feet built per day holding all other factors constant, and that a higher GDP per capita decreases it. The APAC region seems to have an advantage in bridge completion times (average feet built per day for APAC is 35.58 vs. 29.6 for the overall data set). However, this does not emerge as statistically significant in an ANOVA analysis.

These two results make intuitive sense when considered together, as the APAC region has the second highest mean of bridge lengths when compared to the other regions in the data set (50640 feet, while the Middle East has the longest bridges at 58321 feet on average; however, there are only five countries in the Middle East in this data set). Furthermore, APAC has the third lowest average GDP per capita after Africa and South America, respectively.

Based on the literature review as well as factors discussed in the introduction, it is logical that GDP per capita is negatively correlated with feet built per day. In more developed countries, "citizen voice" regarding construction, the importance given to the immediately impacted residents, and environmental impact studies that are completed could be some of the reasons why more advanced countries appear to complete bridges slower (Brooks and Liscow 2019).

It is interesting to note that percentage of GDP invested in infrastructure did not have a significant impact on feet built per day in this analysis. This figure is frequently used when comparing the U.S. vs. other countries in contexts to suggest that this is one of the reasons why the U.S. is slow at completing major infrastructure projects; however, no evidence to support this was found as a part of this study. However, there is still additional research that must be done to determine how this measure affects quality of infrastructure outcomes.

Interestingly, quality of infrastructure was also not a significant predictor of feet built per day. This can be attributed to the fact that the World Bank Quality of Overall Infrastructure Index is an indication of overall infrastructure and not only transportation infrastructure, or more specifically, bridges, that this study focuses on.

4.2. Further Considerations

While this study only focuses on a subset of variables that were hypothesized to be of importance based on the previous background reading and literature review, there are many more variables that are instrumental in determining infrastructure speed. Other variables that were considered were cost, material for main span, a proxy for re-settlement costs, corruption perceptions index, and minimum wage.

Cost was only available for about twenty percent of the bridges and it was not feasible to get a proxy for re-settlement costs in time series format, as construction start dates date back to the 1960's in this dataset. Other suggested variables were not collected because of their high collinearity with the other variables used in the analysis.

Furthermore, one big concern was the non-uniform distribution of data points across regions, making the conclusions and estimates for Africa (n=2) , Middle East (n=5), and South America (n=7) unreliable. Also, regions and countries can't be directly compared as infrastructure spending, financing and planning mechanisms vary across countries. For example, the U.S. mostly relies on local and state spending for its infrastructure needs, while European countries fund most of their spending on infrastructure at the National level (McBride and Siripurapu 2021). The primary mechanism to fund transportation infrastructure in the U.S. is through the Highway Trust Fund, which raises money through gas and transportation related taxes that have largely stayed stable over the last twenty years (McBride and Siripurapu 2021). Furthermore, labor costs are different among countries as well as the nature of the unions. Although most of Western Europe is more unionized than the U.S., some argue that because the U.S. unions are less flexible, they pay "two or four workers to do what one worker would do abroad" (Marshall 2021). From the analysis and conclusions reached in this study, it is apparent that the reason China seems to be building bridges faster can be explained by the start date and length of the bridges there, as well as its level of GDP per capita and property rights. Furthermore, it is worth noting that richer countries do not necessarily build bridges faster.

References

Areddy, J. T. (2021, April 3). *What the U.S. can learn from China's infatuation with infrastructure*. WSJ. https://www.wsj.com/articles/what-the-u-s-can-learn-from-chinas-infatuation-with-infrastructure-11617442201?mod=searchresults_pos3&page=1

Brooks, L., & Liscow, Z. (2019). Infrastructure Costs. *Hutchins Center on Fiscal & Monetary Policy at Brookings*.

Bui, N. (2020). Implementation of Building Information modeling in Vietnamese infrastructure construction: A case study of institutional influences on a bridge project (Vol. 86, Issue 4, p. e12128). City University of Hong Kong. https://doi.org/doi:10.1002/isd2.12128

Calderón, César, Enrique Moral-Benito, and Luis Servén. 2011. *Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach*. http://hdl.handle.net/10986/3446.

Chantal C. Cantarelli and Bent Flyvbjerg. 2013. "Mega-Projects' Cost Performance and Lock-in: Problems and Solutions." In International Handbook on Mega-Projects, 333-355: Edward Elgar Publishing. doi:10.4337/9781781002308.00023. http://www.elgaronline.com/view/10.4337/9781781002308.00023.xml.

Civic-military dictatorship of Uruguay. (n.d.). From Wikipedia, the free encyclopedia. https://en.wikipedia.org/wiki/Civic-military_dictatorship_of_Uruguay#:~:text=The%20civic%2Dmilitary%20dictatorship%20of,)%20until%20February%2028%2C%201985

Danyang–Kunshan grand bridge. (2011, July 9). Wikipedia, the free encyclopedia. Retrieved April 29, 2021, from https://en.wikipedia.org/wiki/Danyang–Kunshan_Grand_Bridge

FACT SHEET: The American jobs plan. (2021, March 31). The White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/

Faridi, Arshi Shakeel and Sameh Monir El-Sayegh. 2006. Significant Factors Causing Delay in the UAE Construction Industry. Vol. 24. London] : E & FN Spon. doi:10.1080/01446190600827033.

Fay, M., Lee, H. I., Mastruzzi, M., Han, S., & Cho, M. (2019). *Hitting the Trillion Mark : A Look at How Much Countries Are Spending on Infrastructure.* (No. 8730).World Bank, Washington, DC. http://hdl.handle.net/10986/31234

Flyvbjerg, Bent, Mette K. Skamris Holm, And Søren L. Buhl. 2004. "What Causes Cost Overrun in Transport Infrastructure Projects?" Transport Reviews 24 (1): 3-18. doi:10.1080/0144164032000080494a. https://search.datacite.org/works/10.1080/0144164032000080494a.

Gould, J. P., & Lemer, A. C. (1994). Toward Infrastructure Improvement : An Agenda for Research. National Academy Press.

He, Qinghua, Junyan Xu, Ting Wang, and Albert P. C. Chan. 2019. "Identifying the Driving Factors of Successful Megaproject Construction Management: Findings from Three Chinese Cases." Frontiers of Engineering Management (Dec 28,). doi:10.1007/s42524-019-0058-8.

Henry, Peter Blair and Camille Gardner. 2019. "Global Infrastructure: Potential, Perils, and a Framework for Distinction." *SSRN Electronic Journal* (-07). doi:10.2139/ssrn.3415942.

Iyer, K. C. and K. N. Jha. 2006. "Critical Factors Affecting Schedule Performance: Evidence from Indian Construction Projects." Journal of Construction Engineering and

Management 132 (8) (Aug): 871-881. doi:10.1061/(ASCE)0733-9364(2006)132:8(871). http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9364(2006)132:8(871).

Marshall, A. (2021, April 21). *Why can't we build infrastructure cheaply, quickly and well?* Governing. https://www.governing.com/community/why-cant-we-build-infrastructure-cheaply-quickly-and-well.html

McBride, J., & Siripurapu, A. (2021, April 8). *The State of U.S. Infrastructure*. Council on Foreign Relations. https://www.cfr.org/backgrounder/state-us-infrastructure

Mladjov, Roumen V.2016. "Part 1: A Study for Structural Efficiency and Economy in Construction ." Structure Magazine.

Ollivier,Gerald Paul; Sondhi,Jitendra; Zhou,Nanyan.2014. High-speed railways in China : a look at construction costs (Chinese). China transport topics;no. 9 Washington, D.C. : World Bank Group.

Richburg, K. B. (2011, October 14). *In booming China, how much infrastructure is too much?* The Washington Post. https://www.washingtonpost.com/business/in-booming-china-how-much-infrastructure-is-too-much/2011/10/14/gIQAYWuv4L_story.html

Smith, N. (2020). *Buttigieg May Finally Give the U.S. Its Infrastructure Day*. Bloomberg.com. https://www.bloomberg.com/opinion/articles/2020-12-16/buttigieg-s-mckinsey-skills-may-get-the-u-s-its-infrastructure-day)

"The Positive Economic Impacts Of Bridges - Bridge Masters". 2018. *Bridge Masters*. https://bridgemastersinc.com/positive-economic-impacts-bridges/.

Transportation infrastructure: Information on bridge conditions. (2015, October 29). U.S. Government Accountability Office (U.S. GAO). https://www.gao.gov/products/gao-16-72r

Woetzel, J., Garemo, N., Mischke, J., Hjerpe, M., & Palter, R. (2016). Bridging Global Infrastructure Gaps. McKinsey Global Institute.

Zhang, Xueqing. 2005. Critical Success Factors for Public–Private Partnerships in Infrastructure Development. Vol. 131. New York : American Society of Civil Engineers. doi:10.1061/(asce)0733-9364(2005)131:1(3).

Zhou, Xuhong and Xigang Zhang. 2019. "Thoughts on the Development of Bridge Technology in China." Engineering (Beijing, China) 5 (6) (Dec): 1120-1130. doi:10.1016/j.eng.2019.10.001. http://dx.doi.org/10.1016/j.eng.2019.10.001.